PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

To:

Assistant Commissioner for Patents
United States Patent and Trademark Office
Box PCT
Washington, D.C.20231
ETATS-UNIS D'AMERIQUE

in its capacity as elected Office

Date of mailing (day/month/year) 13 June 2000 (13.06.00)	
International application No. PCT/US99/11617	**Applicant's or agent's file reference** 587-68 EPO/P
International filing date (day/month/year) 26 May 1999 (26.05.99)	**Priority date** (day/month/year) 27 May 1998 (27.05.98)
Applicant DE TULLIO, Robert et al	

1. The designated Office is hereby notified of its election made:

[X] in the demand filed with the International Preliminary Examining Authority on:

21 December 1999 (21.12.99)

[ ] in a notice effecting later election filed with the International Bureau on:

2. The election [X] was

[ ] was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland**	Authorized officer Nestor Santesso
Facsimile No.: (41-22) 740.14.35	Telephone No.: (41-22) 338.83.38

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION CONCERNING SUBMISSION OR TRANSMITTAL OF PRIORITY DOCUMENT

(PCT Administrative Instructions, Section 411)

To:

ZUSCHLAG, Steven, T.
Hoffmann & Baron, LLP
6900 Jericho Turnpike
Syosset, NY 11791
ETATS-UNIS D'AMERIQUE

Date of mailing (day/month/year) 26 May 2000 (26.05.00)	
Applicant's or agent's file reference 587-68 EPO/P	**IMPORTANT NOTIFICATION**
International application No. PCT/US99/11617	International filing date (day/month/year) 26 May 1999 (26.05.99)
International publication date (day/month/year) 02 December 1999 (02.12.99)	Priority date (day/month/year) 27 May 1998 (27.05.98)
Applicant PORTA SYSTEMS CORPORATION et al	

1. The applicant is hereby notified of the date of receipt (except where the letters "NR" appear in the right-hand column) by the International Bureau of the priority document(s) relating to the earlier application(s) indicated below. Unless otherwise indicated by an asterisk appearing next to a date of receipt, or by the letters "NR", in the right-hand column, the priority document concerned was submitted or transmitted to the International Bureau in compliance with Rule 17.1(a) or (b).

2. This updates and replaces any previously issued notification concerning submission or transmittal of priority documents.

3. An **asterisk(*)** appearing next to a date of receipt, in the right-hand column, denotes a priority document submitted or transmitted to the International Bureau but not in compliance with Rule 17.1(a) or (b). In such a case, **the attention of the applicant is directed** to Rule 17.1(c) which provides that no designated Office may disregard the priority claim concerned before giving the applicant an opportunity, upon entry into the national phase, to furnish the priority document within a time limit which is reasonable under the circumstances.

4. The **letters "NR"** appearing in the right-hand column denote a priority document which was not received by the International Bureau or which the applicant did not request the receiving Office to prepare and transmit to the International Bureau, as provided by Rule 17.1(a) or (b), respectively. In such a case, **the attention of the applicant is directed** to Rule 17.1(c) which provides that no designated Office may disregard the priority claim concerned before giving the applicant an opportunity, upon entry into the national phase, to furnish the priority document within a time limit which is reasonable under the circumstances.

Priority date	Priority application No.	Country or regional Office or PCT receiving Office	Date of receipt of priority document
27 May 1998 (27.05.98)	98304171.6	EP	17 May 2000 (17.05.00) *

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland

Facsimile No. (41-22) 740.14.35

Authorized officer

Sean Taylor

Telephone No. (41-22) 338.83.38

PATENT COOPERATION TREATY

09/701223

JAN 24 2000

From the INTERNATIONAL SEARCHING AUTHORITY

To:
STEVEN T. ZUSCHLAG
HOFFMAN & BARON, LLP
6900 JERICHO TURNPIKE
SYOSSET, NY 11791

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT OR THE DECLARATION

(PCT Rule 44.1)

	Date of Mailing (*day/month/year*) 20 JAN 2000
Applicant's or agent's file reference 587-68 EPO/P	FOR FURTHER ACTION See paragraphs 1 and 4 below
International application No. PCT/US99/11617	International filing date (*day/month/year*) 26 May 1999 (26.05.1999)
Applicant PORTA SYSTEMS CORPORATION	

1. ☒ The applicant is hereby notified that the international search report has been established and is transmitted herewith.
Filing of amendments and statement under Article 19:
The applicant is entitled, if he so wishes, to amend the claims of the international application (see Rule 46):

When? The time limit for filing such amendments is normally 2 months from the date of transmittal of the international search report; however, for more details, see the notes on the accompany sheet.

Where? Directly to the International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland
Facsimile No.: (41-22) 740.14.35

For more detailed instructions, see the notes on the accompanying sheet.

2. ☐ The applicant is hereby notified that no international search report will be established and that the declaration under Article 17(2)(a) to that effect is transmitted herewith.

3. ☐ **With regard to the protest** against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:

☐ the protest together with the decision thereon has been transmitted to the International Bureau together with the applicant's request to forward the texts of both the protest and the decision thereon to the designated Offices.

☐ no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. **Further action(s):** The applicant is reminded of the following:

Shortly after 18 months from the priority date, the international application will be published by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application , or of the priority claim, must reach the International Bureau as provided in rules 90 *bis* 1 and 90 *bis* 3, respectively, before the completion of the technical preparations for international publication.

Within 19 months from the priority date, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase until 30 months from the priority date (in some Offices even later).

Within 20 months from the priority date, the applicant must perform the prescribed acts for entry into the national phase before all designated Offices which have not been elected in the demand or in a later election within 19 months from the priority date or could not be elected because they are not bound by Chapter II.

Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703)305-3230	Authorized officer Paul A Loomis Joni Hill Telephone No. (703) 305-4700

Form PCT/ISA/220 (July 1998)

PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

To:
STEVEN T. ZUSCHLAG
HOFFMAN & BARON, LLP
6900 JERICHO TURNPIKE
SYOSSET, NY 11791

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT OR THE DECLARATION

(PCT Rule 44.1)

	Date of Mailing (*day/month/year*) 20 JAN 2000
Applicant's or agent's file reference 587-68 EPO/P	FOR FURTHER ACTION See paragraphs 1 and 4 below
International application No. PCT/US99/11617	International filing date (*day/month/year*) 26 May 1999 (26.05.1999)
Applicant PORTA SYSTEMS CORPORATION	

1. ☒ The applicant is hereby notified that the international search report has been established and is transmitted herewith.

Filing of amendments and statement under Article 19:
The applicant is entitled, if he so wishes, to amend the claims of the international application (see Rule 46):

When? The time limit for filing such amendments is normally 2 months from the date of transmittal of the international search report; however, for more details, see the notes on the accompany sheet.

Where? Directly to the International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland
Facsimile No.: (41-22) 740.14.35

For more detailed instructions, see the notes on the accompanying sheet.

2. ☐ The applicant is hereby notified that no international search report will be established and that the declaration under Article 17(2)(a) to that effect is transmitted herewith.

3. ☐ **With regard to the protest** against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:

☐ the protest together with the decision thereon has been transmitted to the International Bureau together with the applicant's request to forward the texts of both the protest and the decision thereon to the designated Offices.

☐ no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. **Further action(s):** The applicant is reminded of the following:

Shortly after 18 months from the priority date, the international application will be published by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application , or of the priority claim, must reach the International Bureau as provided in rules 90 *bis* 1 and 90 *bis* 3, respectively, before the completion of the technical preparations for international publication.

Within 19 months from the priority date, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase until 30 months from the priority date (in some Offices even later).

Within 20 months from the priority date, the applicant must perform the prescribed acts for entry into the national phase before all designated Offices which have not been elected in the demand or in a later election within 19 months from the priority date or could not be elected because they are not bound by Chapter II.

Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703)305-3230	Authorized officer Paul A Loomis Joni Hill Telephone No. (703) 305-4700

Form PCT/ISA/220 (July 1998)

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference 587-68 EPO/P	**FOR FURTHER ACTION**	see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.
International application No. PCT/US99/11617	International filing date (*day/month/year*) 26 May 1999 (26.05.1999)	(Earliest) Priority Date (*day/month/year*) 27 May 1998 (27.05.1998)
Applicant PORTA SYSTEMS CORPORATION		

This international search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 4 sheets.

☒ It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the Report**
   a. With regard to the **language**, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.
   ☐ the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).
   b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing:
   ☐ contained in the international application in written form.
   ☐ filed together with the international application in computer readable form.
   ☐ furnished subsequently to this Authority in written form.
   ☐ furnished subsequently to this Authority in computer readable form.
   ☐ the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
   ☐ the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.
2. ☒ **Certain claims were found unsearchable** (See Box I).
3. ☐ **Unity of invention is lacking** (See Box II).
4. With regard to the **title**,
   ☒ the text is approved as submitted by the applicant.
   ☐ the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,
   ☐ the text is approved as submitted by the applicant.
   ☒ the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No. 3
   ☐ as suggested by the applicant. ☐ None of the figures
   ☒ because the applicant failed to suggest a figure.
   ☐ because this figure better characterizes the invention.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/11617

Box I Observations where certain claims were found unsearchable (Continuation of Item 1 of first sheet)

This international report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claim Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claim Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☒ Claim Nos.: 4-7
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of Item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.
☐ No protest accompanied the payment of additional search fees.

Box III TEXT OF THE ABSTRACT (Continuation of Item 5 of the first sheet)

The technical features mentioned in the abstract do not include a reference sign between parentheses (PCT Rule 8.1(d)).

NEW ABSTRACT

A method of testing a telecommunications line (7) by using the following method. Applying a first AC test signal to a communicaitons line (7) by tone generator (23) having a first frequency and then measuring the response to the first test signal. Applying a second AC test signal to the same communications line (7) with a different frequency and measuring the response. Calculating one or more line parameters based on the two measured responses.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/11617

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) : H04M 1/24
US CL : 379/6, 26, 30; 324/526

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 379/1, 6, 21, 26, 27, 30; 324/526, 658, 691

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
NONE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,063,585 A (SHAPIRO) 05 November 1991, see col.4 line 4 through line 28.	8, 13
---		---
A		1-3 and 9-12
X	US 5,073,902 A (MASUKAWA et al) 17 December 1991, see figure 3.	8, 13
---		---
A		1-3 and 9-12
X	US 5,625,667 A (VOGT, III et al) 29 April 1997, see figure 5	8, 13
---		---
A		1-3 and 9-12
A,P	US 5,864,602 A (NEEDLE) 26 January 1999, see abstract and figure 2.	1-3 and 8-13
A	US 5,465,287 A (EGOZI) 07 November 1995, see abstract and figure5.	1-3 and 8-13

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
11 November 1999 (11.11.1999)	20 JAN 2000
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703)305-3230	Authorized officer Paul A Loomis Telephone No. (703) 305-4700

Form PCT/ISA/210 (second sheet) (July 1998)

09/701223

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

REC'D 27 MAR 2001
WIPO PCT

14

Applicant's or agent's file reference 587-68 EPO/P	**FOR FURTHER ACTION**	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
International application No. PCT/US99/11617	International filing date *(day/month/year)* 26 MAY 1999	Priority date *(day/month/year)* 27 MAY 1998
International Patent Classification (IPC) or national classification and IPC IPC(7): H04M 1/24 and US Cl.:379/1, 6, 21, 26, 27, 30; 324/526, 658, 691		
Applicant PORTA SYSTEMS CORPORATION		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 4 sheets.

   ☐ This report is also accompanied by ANNEXES, i.e., sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority. (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 0 sheets.

3. This report contains indications relating to the following items:

   I ☒ Basis of the report

   II ☐ Priority

   III ☐ Non-establishment of report with regard to novelty, inventive step or industrial applicability

   IV ☐ Lack of unity of invention

   V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

   VI ☐ Certain documents cited

   VII ☐ Certain defects in the international application

   VIII ☐ Certain observations on the international application

RECEIVED
MAY 15 2001
TECHNOLOGY CENTER 2600

Date of submission of the demand	Date of completion of this report
21 DECEMBER 1999	11 MARCH 2001
Name and mailing address of the IPEA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer CURTIS KUNTZ Telephone No. (703) 305-4708

Form PCT/IPEA/409 (cover sheet) (July 1998)★

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.
PCT/US99/11617

I. Basis of the report

1. With regard to the **elements** of the international application:*

☐ the international application as originally filed

☒ the description:
pages 1-19 , as originally filed
pages NONE , filed with the demand
pages NONE , filed with the letter of _____

☒ the claims:
pages 20-22 , as originally filed
pages NONE , as amended (together with any statement) under Article 19
pages NONE , filed with the demand
pages NONE , filed with the letter of _____

☒ the drawings:
pages 8 , as originally filed
pages NONE , filed with the demand
pages NONE , filed with the letter of _____

☒ the sequence listing part of the description:
pages NONE , as originally filed
pages NONE , filed with the demand
pages NONE , filed with the letter of _____

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.
These elements were available or furnished to this Authority in the following language _____ which is:

☐ the language of a translation furnished for the purposes of international search (under Rule 23.1(b)).

☐ the language of publication of the international application (under Rule 48.3(b)).

☐ the language of the translation furnished for the purposes of international preliminary examination (under Rules 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

☐ contained in the international application in printed form.

☐ filed together with the international application in computer readable form.

☐ furnished subsequently to this Authority in written form.

☐ furnished subsequently to this Authority in computer readable form.

☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

☐ The statement that the information recorded in computer readable form is identical to the writen sequence listing has been furnished.

4. ☒ The amendments have resulted in the cancellation of:

☒ the description, pages NONE

☒ the claims, Nos. NONE

☒ the drawings, sheets/~~fig~~ NONE

5. ☐ This report has been drawn as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).**

** Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17).*

***Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.*

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.
PCT/US99/11617

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. statement

Novelty (N)	Claims	3-7 AND 10-11	YES
	Claims	1-2, 8-9 AND 12-13	NO
Inventive Step (IS)	Claims	NONE	YES
	Claims	1-13	NO
Industrial Applicability (IA)	Claims	1-13	YES
	Claims	NONE	NO

2. citations and explanations (Rule 70.7)

Claims 1-2 and 12 lack novelty under PCT Article 33(2) as being anticipated by Shapiro (US Pat# 5,063,585).

Regarding claims 1-2 and 12, Shapiro teaches a telephone subscriber line fault detection comprising of sending a first and second AC test signal (see column 4 lines 4-28 and fig. 3) when testing a subscriber line.

Claims 8-9 and 13 lack novelty under PCT Article 33(2) as being anticipated by Masukawa et al. (US Pat# 5,073,920).

Regarding claims 8-9 and 13, masukawa teaches a method and apparatus of measuring a subscriber line comprising of sending two test signals on respective lines (see fig. 3).

Claims 3-5 lack an inventive step under PCT Article 33(3) as being obvious over Shapiro et al. in view of Ingle (US Pat# 4,768,203).

Regarding claims 3-5, Shapiro fails to teach the claimed subject matter but Ingle teaches signal-to-noise ratio testing in adaptive differential pulse code modulation in (see entire disclosure) wherein a plurality of multi-tone frequencies can be used in analyzing the quality of a loop (see figs. 3-6 and table 1 of column 6).

Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to incorporate the teaching of Ingle into that of Shapiro thus making it possible to test a loop by using multi-frequency tones.

Claim 6 lack an inventive step under PCT Article 33(3) as being obvious over Shapiro in view of Vogt et al. (US Pat# 5,625,667).

Regarding claim 6, Shapiro fails to teach the claimed subject matter but Vogt teaches a method of predicting voltages in telephone line measurement comprising of being able to perform multi-test to determine values of electrical parameters. Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to incorporate the teaching of Vogt into that of Shapiro thus making it possible to (Continued on Supplemental Sheet.)

Supplemental Box
(To be used when the space in any of the preceding boxes is not sufficient)

Continuation of: Boxes I - VIII

V. 2. REASONED STATEMENTS - CITATIONS AND EXPLANATIONS (Continued):
perform a plurality of test in measuring different parameters in assessing the quality of a component.

Claim 7 lack an inventive step under PCT Article 33(3) as being obvious over Shapiro in view of Masukawa.

Regarding claim 7, Shapiro fails to teach the claimed subject matter but Masukawa teaches a method for measuring a subscriber line comprising of measuring a plurality of impedances on two lines namely; line A and B (see fig. 3).

Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to incorporate the teaching of Masukawa into that of Shapiro thus making it possible to detect ad measure impedances of a telephone line in a short time with high accuracy.

Claims 10-11 lack an inventive step under PCT Article 33(3) as being obvious over Masakawa in view of Ingle.

Regarding claims 10-11, Masakawa fails to teach the claimed subject matter but Ingle teaches signal-to-noise ratio testing in adaptive differential pulse code modulation in (see entire disclosure) wherein a plurality of multi-tone frequencies can be used in analyzing the quality of a loop (see figs. 3-6 and table 1 of column 6).

Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to incorporate the teaching of Ingle into that of Masakawa thus making it possible to test a loop by using multi-frequency tones.

---------- NEW CITATIONS ----------
US 4,768,203 A (INGLE) 30 AUGUST 1988, SEE ENTIRE DISCLOSURE.

CLAIMS

Sub A1

1. A method of testing a telecommunications system, the method comprising;

1) applying a first AC test signal having a first signal frequency to the system and measuring the response of the system to the first test signal;

2) applying a second AC test signal having a second signal frequency different to the first signal frequency to the system and measuring the response of the system to the second test signal; and

3) calculating one or more parameters of the system from the responses measured in steps 1) and 2).

2. A method according to claim 1 wherein the first and second test signals are applied at different times.

3. A method according to claim one or two wherein one or both of the test signals has a substantially sinusoidal waveform.

4. A method according to any of the preceding claims wherein less than five cycles of each signal is applied to the system.

5. A method according to any of the preceding claims wherein the test signals are each applied to the system through a known impedance.

6. A method according to any of the preceding claims further comprising applying;

4) applying one or more additional test signals to the system and measuring the response of the system to the or each test signal; and

wherein step 3) comprises calculating one or more parameters of the system from the responses measured in steps 1), 2) and 4).

7. A method according to any of the preceding claims wherein the system comprises first and second transmission lines, and wherein each step of applying a test signal and measuring the response of the system comprises

sub A1 cont.

a) applying the test signal to the first line and monitoring the response of the first line and the second line to the test signal; and

b) applying the test signal to the second line and monitoring the response of the second line and the first line to the second test signal.

8. A method of testing a telecommunications system comprising first and second transmission lines, the method comprising

1) applying a first test signal to the first line and measuring the response of the first line and the second line to the first test signal;

2) applying a second test signal to the second line and measuring the response of the second line and the first line to the second test signal; and

3) calculating one or more parameters of the telecommunications system from the responses measured in steps 1) and 2).

9. A method according to any claim 8 wherein the first and second signals each comprise AC signals.

10. A method according to claim 9 wherein the signal frequencies of the first and second test signals are substantially identical.

11. A method according to claim 10 wherein the first and second test signals have a known phase relationship.

12. Apparatus for testing a telecommunications system, the apparatus comprising;

1) means for applying a first AC test signal having a first signal frequency to the system;

2) means for measuring the response of the system to the first test signal;

3) means for applying a second AC test signal having a second signal frequency different to the first signal frequency to the system;

4) means for measuring the response of the system to the second test signal; and

Sub A1 conc.

5) means for calculating one or more parameters of the system from the responses measured in steps 1) and 2).

13. Apparatus for testing a telecommunications system comprising first and second transmission lines, the apparatus comprising

1) means for applying a first test signal to the first line

2) means for measuring the response of the first line and the second line to the first test signal;

3) means for applying a second test signal to the second line

4) means for measuring the response of the second line and the first line to the second test signal; and

5) means for calculating one or more parameters of the telecommunications system from the responses measured in steps 1) and 2).

PCT WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : **H04M 1/24** | **A3**

(11) International Publication Number: **WO 99/62188**

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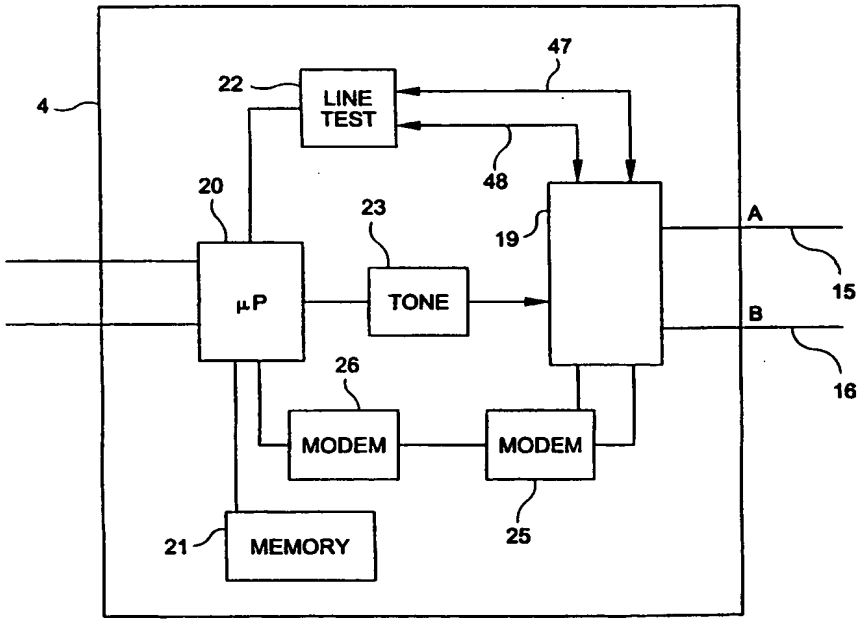

(57) Abstract

A method of testing a telecommunications line by using the following method. Applying a first AC test signal to a communications line (7) by tone generator (23) having a first frequency and then measuring the response to the first test signal. Applying a second AC test signal to the same communications line (7) with a different frequency and measuring the response. Calculating one or more line parameters based on the two measured responses.

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AMENDED CLAIMS
[received by the International Bureau on 22 February 2000 (22.02.00);
original claims 3-7 amended; remaining claims unchanged (3 pages)]

1. A method of testing a telecommunications system, the method comprising;

1) applying a first AC test signal having a first signal frequency to the system and measuring the response of the system to the first test signal;

2) applying a second AC test signal having a second signal frequency different to the first signal frequency to the system and measuring the response of the system to the second test signal; and

3) calculating one or more parameters of the system from the responses measured in steps 1) and 2).

2. A method according to claim 1 wherein the first and second test signals are applied at different times.

3. A method according to claim 1 wherein one or both of the test signals has a substantially sinusoidal waveform.

4. A method according to claim 1 wherein less than five cycles of each signal is applied to the system.

5. A method according to claim 1 wherein the test signals are each applied to the system through a known impedance.

6. A method according to claim 1 further comprising applying;

4) applying one or more additional test signals to the system and measuring the response of the system to at least one test signal; and

wherein step 3) comprises calculating one or more parameters of the system from the responses measured in steps 1),2) and 4).

7. A method according to claim 1 wherein the system comprises first and second transmission lines, and wherein each step of applying a test signal and measuring the response of the system comprises

a) applying the test signal to the first line and monitoring the response of the first line and the second line to the test signal; and

b) applying the test signal to the second line and monitoring the response of the second line and the first line to the second test signal.

8. A method of testing a telecommunications system comprising first and second transmission lines, the method comprising

1) applying a first test signal to the first line and measuring the response of the first line and the second line to the first test signal;

2) applying a second test signal to the second line and measuring the response of the second line and the first line to the second test signal; and

3) calculating one or more parameters of the telecommunications system from the responses measured in steps 1) and 2).

9. A method according to claim 8 wherein the first and second signals each comprise AC signals.

10. A method according to claim 9 wherein the signal frequencies of the first and second test signals are substantially identical.

11. A method according to claim 10 wherein the first and second test signals have a known phase relationship.

12. Apparatus for testing a telecommunications system, the apparatus comprising;

1) means for applying a first AC test signal having a first signal frequency to the system;

2) means for measuring the response of the system to the first test signal;

3) means for applying a second AC test signal having a second signal frequency different to the first signal frequency to the system;

4) means for measuring the response of the system to the second test signal; and

5) means for calculating one or more parameters of the system from the responses measured in steps 1) and 2).

13. Apparatus for testing a telecommunications system comprising first and second transmission lines, the apparatus comprising

1) means for applying a first test signal to the first line

2) means for measuring the response of the first line and the second line to the first test signal;

3) means for applying a second test signal to the second line;

4) means for measuring the response of the second line and the first line to the second test signal; and

5) means for calculating one or more parameters of the telecommunications system from the responses measured in steps 1) and 2).

INTERNATIONAL SEARCH REPORT

International application No.
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A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) : H04M 1/24
US CL : 379/6, 26, 30; 324/526

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 379/1, 6, 21, 26, 27, 30; 324/526, 658, 691

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
NONE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,063,585 A (SHAPIRO) 05 November 1991, see col.4 line 4 through line 28.	8, 13
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A		1-3 and 9-12
X	US 5,073,902 A (MASUKAWA et al) 17 December 1991, see figure 3.	8, 13
—		---
A		1-3 and 9-12
X	US 5,625,667 A (VOGT, III et al) 29 April 1997, see figure 5	8, 13
—		---
A		1-3 and 9-12
A,P	US 5,864,602 A (NEEDLE) 26 January 1999, see abstract and figure 2.	1-3 and 8-13
A	US 5,465,287 A (EGOZI) 07 November 1995, see abstract and figure5.	1-3 and 8-13

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
11 November 1999 (11.11.1999)	20 JAN 2000
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231	Authorized officer Paul A Loomis
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INTERNATIONAL SEARCH REPORT

'rnational application No.
PCT/US99/11617

Box I Observations where certain claims were found unsearchable (Continuation of Item 1 of first sheet)

This international report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claim Nos.:
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2. ☐ Claim Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☒ Claim Nos.: 4-7
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of Item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

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4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.
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Published
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(54) Title: APPARATUS AND METHOD FOR TESTING A TELECOMMUNICATIONS SYSTEM

(57) Abstract

A method of testing a telecommunications system (7), the method comprising: 1) applying a first AC test signal having a first signal frequency to the system and measuring the response of the system to the first test signal; 2) applying a second AC test signal having a second signal frequency different to the first signal frequency to the system and measuring the response of the system to the second test signal; and 3) calculating one or more parameters of the system from the responses measured in steps 1) and 2).

APPARATUS AND METHOD FOR TESTING A TELECOMMUNICATIONS SYSTEM

The present invention relates to a method and apparatus for testing a telecommunications system.

Conventional apparatus for testing telecommunications systems applies a test signal to the telecommunications system and, by analysing the response of the system to the test signal, calculates one or more parameters of the system in accordance with a chosen line model.

A problem with conventional methods is that it is not possible to determine the series line resistance of a transmission line in the system under test.

In accordance with a first aspect of the present invention there is provided a method of testing a telecommunications system, the method comprising;

1) applying a first AC test signal having a first signal frequency to the system and measuring the response of the system to the first test signal;

2) applying a second AC test signal having a second signal frequency different to the first signal frequency to the system and measuring the response of the system to the second test signal; and

3) calculating one or more parameters of the system from the responses measured in steps 1) and 2).

The first aspect of the present invention provides additional data which can be analyzed to calculate system parameters (e.g. electrical parameters such as resistance or capacitance) which have been previously difficult or impossible to determine - such as series line resistance.

The first and second AC test signals may be applied at the same time, in the form of a multi-frequency signal. However preferably the first and second test signals are applied at different times.

The wave form of the first and/or second test signal may be non-sinusoidal (for instance a square wave or saw-tooth wave) but preferably the test signals have a

substantially sinusoidal waveform. This simplifies the calculation procedure.

It is important that the method can test the telecommunications system quickly - this enables a number of lines within the system to be tested over a given period. Therefore preferably less than 5 cycles of each signal is applied to the system. In a preferred embodiment, two cycles of each signal are applied to the system.

Typically the test signals are each applied to the system through a known impedance. The voltage drop across the known impedance can then be used to calculate a characteristic impedance of the telecommunications system.

If additional data is required, then one or more additional test signals may be applied to the system. The one or more additional test signals may comprise AC test signals with a signal frequency different to the signal frequency of the first and second test signals. However preferably the or each additional test signal comprises a DC test signal.

Typically the system comprises first and second transmission lines (conventionally known as A and B lines). Conventionally an AC test signal is applied simultaneously to both lines (either in phase or in anti-phase) and the response of only one of the lines is monitored. In a preferred embodiment the step of applying a test signal and measuring the response of the system comprises:

a) applying the test signal to the first line and monitoring the response of the first line and the second line to the test signal; and

b) applying the test signal to the second line and monitoring the response of the second line and the first line to the second test signal.

By monitoring the response of both lines, additional parameters can be obtained.

In accordance with a second aspect of the present invention there is provided a method of testing a

telecommunications system comprising first and second transmission lines, the method comprising

1) applying a first test signal to the first line and monitoring the response of the first line and the second line to the first test signal;

2) applying a second test signal to the second line and monitoring the response of the second line and the first line to the second test signal; and

3) calculating one or more parameters of the telecommunications system from the responses measured in steps 1) and 2).

The second aspect of the present invention enables a number of system parameters to be calculated. In contrast with conventional systems, the response of both the first line and the second line is monitored.

The first and second signals may be DC signals, or alternatively the first test signal and/or the second test signal may comprise an AC signal. In a preferred example the signal frequencies of the first and second test signals are substantially identical. Alternatively, the signal frequency of the first and second test signals may be different.

The first and second test signals may be generated independently, but preferably they have a known phase relationship. This enables the parameters to be calculated more easily in step 3).

A number of embodiments of the present invention will now be described with reference to the accompanying drawings in which:-

Figure 1 is a schematic illustration of apparatus for testing a telecommunications system;

Figure 2 illustrates the remote test unit, exchange and telephone in more detail;

Figure 3 illustrates the functional structure of the remote test unit;

Figure 4 is a schematic diagram illustrating the arrangement of the line test unit;

Figure 5 illustrates part of the measurement cycle;

Figure 6 illustrates the full complex voltages measured by the AC measurement cycle;

Figure 7 is a first example of a line model;

Figure 8 is an enhanced line model;

Figure 9 is a line termination model, discussed in Appendix 4; and

Figure 10 is a third example of a line model.

Figure 1 is a schematic diagram of a system for remotely testing a telecommunications line. An operator station 1 is connected to a general controller 2 which inputs and outputs signals to/from a telecommunications medium 3 (which may comprise a PSTN or X.25 network). A telephone 6 is connected to a local exchange 5 via a land line 7. A remote test unit (RTU) 4 is connected to the exchange 5 in order to test the land line 7. Figure 1 illustrates a control path 8 and a test path 9.

As can be seen in Figure 2, the line 7 comprises a pair of lines 10,11 (configured as a twisted pair) known conventionally as "A" and "B" lines. An exchange feed comprising a 50V battery 12 is connected to the A and B lines 10,11 during normal operation via 200 ohm resistors 13,14. In order to test the line 7, the RTU control line 8 switches the A and B lines 10,11 over to the test line 9 (which in turn comprises a pair of input lines 15,16). The RTU communicates with the general controller 2 via a V.24 link (17) or 300 V.21 link (18).

The internal functional structure of the RTU 4 is shown in Figure 3. The A and B input lines 15,16 are connected to a line access unit 19 which controls the input and output of signals to/from the line 7. A line test unit 22 controls testing of the line 7, a tone generator 23 generates tone signals 24 which can be output onto the line 7, and voice modems 25,26 handle voice signals which can be communicated between the operator station 1 and telephone set 6. The RTU is controlled by a microprocessor 20 and data acquired is saved in a memory 21.

The line test unit 22 is illustrated in more detail in Figure 4. A pair of signal generators 30,31 generate sine wave signals which are amplified by respective amplifiers 32,33. The signals output by amplifiers 32,33 have a range of +/-200V and a bandwidth of 10kHz. The signal generators 30,31 are run synchronously from the same clock by a controller 34. This ensures that the signals have a known phase relationship. Each line has a respective set of output resistors 35-40 (each having a known resistance within a tolerance of 1%). Each output resistor has an associated switch 41-46 which can be closed by controller 34 to connect the associated output resistor between the amplifier and output line 47,48. Typical resistance values for the three output resistors on each line are 200,1M and 100K ohms. The voltage on line A is measured by a voltmeter 49 and the voltage on line B is measured by a voltmeter 50. The voltages are digitised by A-D converter 51 which samples at 12 kHz. Phase and RMS voltage values are calculated by processor 52 and stored in memory 53.

Referring to Figure 5, the line test procedure is as follows:

Step 1 - open all output resistor switches 41-46 and measure DC voltage on A and B lines.

Step 2 - adjust DC bias of amplifier 32 so that amplified signal is centred on line A DC voltage level.

Step 3 - adjust DC bias of amplifier 33 so that amplified signal is centred on line B DC voltage level.

Step 4 - set signal generators 30,31 to generate a DC signal.

Step 5 - close a selected one of the line A output resistor switches 41-43.

Step 6 - store DC voltages on voltmeters 39,50 in memory 53.

Step 7 - open selected line A switch and close a selected one of the line B output resistor switches 44-46.

Step 8 - store DC voltages on voltmeters 39,50 in memory 53.

Step 9 - set signal generators 30,31 to 2.75Hz.

Step 10 - after first cycle, perform digital fourier transform (at 2.75Hz) of signals from voltmeters 49,50 over second cycle and store amplitude and phase values in memory 53.

Step 11 - open selected switch 44-46 (line B) and close switch 41-43 associated with selected output resistor (line A).

Step 12 - after first cycle, perform digital fourier transform (at 2.75Hz) of signals from voltmeters 49,50 over second cycle and store amplitude and phase values in memory 53.

Step 13 - adjust frequency of signal generators 30,31 to 5Hz.

Steps 14-16 - repeat steps 10-12 at 5Hz.

The resulting AC data can be represented as four complex voltage values as illustrated in Figure 6, where:

V_{A1} is the voltage measured by voltmeter 49 (line A) with signal being applied to line A;

V_{B1} is the voltage measured by voltmeter 50 (line B) with signal being applied to line A;

V_{A2} is the voltage measured by voltmeter 49 (line A) with signal being applied to line B; and

V_{B2} is the voltage measured by voltmeter 50 (line B) with signal being applied to line B.

The four complex values can then be used to calculate four impedance parameters Z as defined below:

$Z_{11}=V_{ae}/I_a$ when line b is open;

$Z_{22}=V_{be}/I_b$ when line a is open;

$Z_{12}=V_{ae}/I_b$ when line a is open; and

$Z_{21}=V_{be}/I_a$ when line b is open;.

where

V_{ae} is the voltage on voltmeter 49 (ie. the voltage from line A to earth);

V_{be} is the voltage on voltmeter 50 (ie. the voltage from line B to earth);

I_a is the current on line 47 (line A); and

I_b is the current on line 48 (line B).

Since the voltages (V_a,V_b) output by the amplifiers 32,33 and the values (R_a,R_b) of the resistors 35-40 are known accurately, the currents I_a and I_b can be eliminated from the expressions for Z as follows:

$Z_{11}=R_aV_{ae}/(V-V_{ae})$;

$Z_{22}=R_bV_{be}/(V-V_{be})$;

$Z_{12}=R_bV_{ae}/(V-V_{be})$; and

$Z_{21}=R_aV_{be}/(V-V_{ae})$.

Once the Z parameters have been calculated as discussed above, they can be used to determine characteristics of the line 7 under test using an algorithm based on a selected line model.

One example of a suitable line model is illustrated in Figure 7. The series resistances of the lines 10,11 between the RTU 4 and the telephone 6 are represented by resistors R_1,R_2. The line termination at telephone 6 is represented by resistors R_5,R_6 and capacitors C_2,C_3. The leakage to ground from the A and B lines is represented by resistors R_3,R_4 and capacitors C_1,C_2. The problem with the line model of Figure 7 is that it is difficult to find ten independent equations based on conventional tests in order to calculate the ten line model parameters. Even if ten independent equations could be found, it would be difficult to solve the ten non-linear equations even by a numerical method.

The alternative line model of Figure 8 reduces the number of parameters to be identified by replacing the line termination parameters R_5,R_6,C_2 and C_3 with a single impedance value Z. In Figure 8 the series resistances of the lines 10,11 between the RTU 4 and the telephone 6 are represented by resistors r_1,r_2 and the leakage to ground from the A and B lines is represented by resistors g_1,g_2 and capacitors C_1,C_2.

A set of equations based on the enhanced line model of Figure 8 can be manipulated into a linear equation system

and a set of symbolic solutions obtained as set out in Appendix 1, Appendix 2 and Appendix 3 below.

Furthermore, the line termination parameters can also be calculated as set out in Appendix 4 below.

The calculated values of the parameters r_1, r_2, g_1, g_2, c_1, c_2 and z are stored at the RTU for later analysis or transmitted back to the operator station 1. The parameters can then be used to identify and characterise any faults on the line 7 such as a break in the line, fault to ground or fault to another line. Furthermore the parameters can be used to determine whether the line 7 is suitable for carrying different communication protocols such as ISDN,DACS,HDSL,CWSS or ADSL.

A further alternative line model is illustrated in Figure 10. It is possible to calculate the parameters of this model using a simplified measurement procedure which uses a DC measurement followed by a single AC measurement (ie. at only one frequency).

Although the line test unit 22 illustrated in Figure 4 is shown with two signal generators 30,31 and two sets of output resistors 41-46, it will be appreciated that a single generator and a single set of resistors could be used, and switched from one line to the other.

Appendix 1

Identification Results

The model parameters including the series resistances are given as follows,

$$r_1 = \frac{n_1 Z_{11b} + Z_{11a}\omega n_2 + \omega n_3 Z_{12a} + Z_{12b}}{\omega n_2} \tag{1}$$

$$r_2 = \frac{n_1 Z_{11b} + Z_{22a}\omega n_3 + \omega n_2 Z_{12a} + Z_{22b}}{\omega n_2} \tag{2}$$

$$g_2 = -\frac{\omega n_2}{(n_1)^2 Z_{11b} + n_1 n_3 Z_{12a}\omega + n_1 Z_{12b} - n_2 Z_{12a}\omega + n_2 n_3 Z_{12b}(\omega)^2 + (n_2)^2 Z_{11b}(\omega)^3} \tag{3}$$

$$g_1 = n_1 g_2 \tag{4}$$

$$c_1 = n_2 g_2 \tag{5}$$

$$c_2 = n_3 g_2$$

$$Z = \frac{\frac{1}{Z_{12}} - g_1 - g_2 - j\omega c_1 - j\omega c_2}{(g_1 + j\omega c_1)(g_2 + j\omega c_2)} \tag{6}$$

where ω is test frequency, Z_{ija} and Z_{ijb}, $i=1,2$, $j=1,2$ are the real and imaginary parts of the Z-parameters respectively, and n_k, $k=1,2,3$ can be calculated from the knowns, whose expressions along with the detailed mathematical manipulations were given in the appendix.

An example

For a simple example to show that the proposed method can solve the problem, let us suppose that

$r_1 = r_2 = 1,$

$g_1 = 2,$

$g_2 = 3,$

$c_1 = 2,$

$c_2 = 4,$

$$Z = \frac{1 - j\omega}{4}$$

For this simple example, the measurements of Z-parameters can be easily simulated by simple calculation as indicated in (7)-(9) in the appendix. They are,

$\omega = 1,$ 10

$$Z_{11a} = \frac{377}{328}$$

$$Z_{11b} = \frac{-51}{328}$$

$$Z_{12a} = \frac{2}{41}$$

$$Z_{12b} = \frac{-5}{82}$$

$$Z_{22a} = \frac{45}{41}$$

$$Z_{22b} = \frac{-5}{41}$$

$$\omega_2 = 2$$

$$Z^2_{11a} = \frac{10145}{9442}$$

$$Z^2_{11b} = \frac{-711}{4721}$$

$$Z^2_{12a} = \frac{50}{4721}$$

$$Z^2_{12b} = \frac{-128}{4721}$$

$$Z^2_{22a} = \frac{4896}{4721}$$

$$Z^2_{22b} = \frac{-488}{4721}$$

substitue them to (27) to (35) to calculate coefficients (See appendix 2 for definition) we get

$$a_1 = \frac{116037}{1548488}$$

$$a_2 = \frac{7392}{193561}$$

$$a_3 = \frac{11709}{193561}$$

$$d_1 = \frac{225645}{1548488}$$

$$d_2 = \frac{-124167}{774244}$$

$$d_3 = \frac{-2613}{387122}$$

$$d_5 = \frac{13131}{193561}$$

$$d_6 = \frac{-28842}{193561}$$

By further substituting to (46) to (48) we get

$$n_1 = \frac{2}{3}$$

$$n_2 = \frac{2}{3}$$

$$n_3 = \frac{4}{3}$$

So we can calculate r_1 and r_2 from (50) and (51), the results are

$r_1 = 1$

$r_2 = 1$

and g2 from (52)

$g_2=3$

from (43) to (45)

$g_1=2$

$c_1=2$

$c_2=4$

which are exactly the same as our assumption. For a more practical example, the results' accuracy relies heavily on the precision of the software. It needs to be studied that what precision is needed for our test purpose.

Discussion and conclusions

- In the report, we suppose that two frequencies are used in the measurements. It is noticed that one of them can be zero, that means we can use a DC test and an AC test to identify all the parameters. But in this case, the formulas are more complicated as less information obtained. In fact, a second order, two variables non-linear equation system has to be solved, maybe numerically. Further study is carrying out along this direction hoping find a way to find a relatively simple symbolic solution.
- The calculation can be further reduced as we use two frequencies with one doubles the other, which is the case in the current test system.
- It is possible to locate leakage fault by using the series resistance.
- The line termination parameters, which are represented by a combined impedance Z in our discussion, can be further identified
- It can be concluded that all the parameters in the enhanced line model can be uniquely identified with two frequencies measurements. For the DC and AC case, the line parameter and the combined line termination can be identified, but the individual line termination parameters remain unsolved

Appendix 2

For a two port network as shown in Figure 8 the Z-parameters can be calculated as follows,

$$Z_{11} = r_1 + \frac{\frac{1}{g_1 + j\omega c_1}\left(Z + \frac{1}{g_2 + j\omega c_2}\right)}{\frac{1}{g_1 + j\omega c_1} + Z + \frac{1}{g_2 + j\omega c_2}}$$

$$= r_1 + \frac{(g_2 + j\omega c_2)Z + 1}{g_1 + g_2 + j\omega c_1 + j\omega c_2 + Z(g_1 + j\omega c_1)(g_2 + j\omega c_2)} \quad (7)$$

$$= r_1 + \frac{(g_2 + j\omega c_2)Z + 1}{\Delta}$$

$$Z_{12} = \frac{\frac{1}{g_1 + j\omega c_1}\frac{1}{g_2 + j\omega c_2}}{\frac{1}{g_1 + j\omega c_1} + Z + \frac{1}{g_2 + j\omega c_2}}$$

$$= \frac{1}{(g_1 + j\omega c)(g_2 + j\omega c_2)\left(\frac{1}{g_1 + j\omega c_1} + Z + \frac{1}{g_2 + j\omega c_2}\right)} \quad (8)$$

$$= \frac{1}{g_1 + g_2 + j\omega c_1 + j\omega c_2 + Z(g_1 + j\omega c_1)(g_2 + j\omega c_2)}$$

$$= \frac{1}{\Delta}$$

$$Z_{22} = r_2 + \frac{\frac{1}{g_2 + j\omega c_2}\left(Z + \frac{1}{g_1 + j\omega c_1}\right)}{\frac{1}{g_1 + j\omega c_1} + Z + \frac{1}{g_2 + j\omega c_2}}$$

$$= r_2 + \frac{(g_1 + j\omega c_1)Z + 1}{g_1 + g_2 + j\omega c_1 + j\omega c_2 + Z(g_1 + j\omega c_1)(g_2 + j\omega c_2)} \quad (9)$$

$$= r_2 + \frac{(g_1 + j\omega c_1)Z + 1}{\Delta}$$

From (8) we can get,

$$Z(g_1 + j\omega c_1)(g_2 + j\omega c_2) = \frac{1}{Z_{12}} - g_1 - g_2 - j\omega c_1 - j\omega c_2 \quad (10)$$

Rewritten (7) as:

$Z_{11} = r_1 + [(g_2 + j\omega c_2)Z + 1]Z_{12}$

multiply $(g_1+j\omega c_1)$, if $(g_1+j\omega c_1) \neq 0$, we get

$$(g_1 + j\omega c_1)Z_{11} = r_1(g_1 + j\omega c_1) + (g_1 + j\omega c_1)[(g_2 + j\omega c_2)Z + 1]Z_{12} \quad (11)$$

$$= r_1(g_1 + j\omega c_1) + [(g_1 + j\omega c_1)(g_2 + j\omega c_2)Z]Z_{12} + (g_1 + j\omega c_1)Z_{12}$$

substitute (10) to (11) to eliminate Z,

$$(g_1 + j\omega c_1)Z_{11} = r_1(g_1 + j\omega c_1) + (\frac{1}{Z_{12}} - g_1 - g_2 - j\omega c_1 - j\omega c_2)Z_{12} + (g_1 + j\omega c_1)Z_{12}$$

$$= r_1(g_1 + j\omega c_1) + 1 - (g_1 + j\omega c_1)Z_{12} - (g_2 + j\omega c_2)Z_{12} + (g_1 + j\omega c_1)Z_{12} \quad (12)$$

$$= r_1(g_1 + j\omega c_1) + 1 - (g_2 + j\omega c_2)Z_{12}$$

Similarly we can get an equation about Z_{22} as

$$(g_2 + j\omega c_2)Z_{22} = r_2(g_2 + j\omega c_2) + 1 - (g_1 + j\omega c_1)Z_{12} \quad (13)$$

We write the Z-parameters in their real and imaginary part as

$$Z_{11} = Z_{11a} + jZ_{11b}$$

$$Z_{12} = Z_{12a} + jZ_{12b} \quad (14)$$

$$Z_{22} = Z_{22a} + jZ_{22b}$$

Substitute (14) to (12) we get

$$(g_1 + j\omega c_1)(Z_{11a} + jZ_{11b}) = r_1(g_1 + j\omega c_1) + 1 - (g_2 + j\omega c_2)(Z_{12a} + jZ_{12b})$$

$$g_1Z_{11a} - \omega c_1Z_{11b} + j(g_1Z_{11b} + Z_{11a}\omega c_1) = r_1g_1 + 1 - g_2Z_{12a} + \omega c_2Z_{12b} + j(r_1\omega c_1 - \omega c_2Z_{12a} - g_2Z_{12b}) \quad (15)$$

By separate real and imaginary part, we get two equations,

$$g_1Z_{11a} - \omega c_1Z_{11b} - r_1g_1 - 1 + g_2Z_{12a} - \omega c_2Z_{12b} = 0 \quad (16)$$

$$g_1Z_{11b} + Z_{11a}\omega c_1 - r_1\omega c_1 + \omega c_2Z_{12a} + g_2Z_{12b} = 0 \quad (17)$$

Be substituting (14) to (13) we can get another two equations in a similar way,

$$g_2Z_{22a} - \omega c_2Z_{22b} - r_2g_2 - 1 + g_1Z_{12a} - \omega c_1Z_{12b} = 0 \quad (18)$$

$$g_2Z_{22b} + Z_{22a}\omega c_2 - r_2\omega c_2 + \omega c_1Z_{12a} + g_1Z_{12b} = 0 \quad (19)$$

When the measurements are taken at two frequencies, we can get another set of equation at frequency ω_2, if we denote the measurements at this frequency by adding a superscript 2 to the corresponding quantities, the equations can be written as follows

$$g_1Z^2_{11a} - \omega_2c_1Z^2_{11b} - r_1g_1 - 1 + g_2Z^2_{12a} - \omega_2c_2Z^2_{12b} = 0 \quad (20)$$

$$g_1Z^2_{11b} + Z^2_{11a}\omega_2c_1 - r_1\omega_2c_1 + \omega_2c_2Z^2_{12a} + g_2Z^2_{12b} = 0 \quad (21)$$

$$g_2Z^2_{22a} - \omega_2c_2Z^2_{22b} - r_2g_2 - 1 + g_1Z^2_{12a} - \omega_2c_1Z^2_{12b} = 0 \quad (22)$$

$$g_2Z^2_{22b} + Z^2_{22a}\omega_2c_2 - r_2\omega_2c_2 + \omega_2c_1Z^2_{12a} + g_1Z^2_{12b} = 0 \quad (23)$$

The problem is to solve equations (16) to (23) for model parameters r_k, g_k and c_k, $k=1,2$.

To eliminate r_1 and r_2, first let (16) – (20), we get,

$$g_1(Z_{11a} - Z^2_{11a}) - c_1(\omega Z_{11b} - \omega_2Z^2_{11b}) + g_2(Z_{12a} - Z^2_{12a}) - c_2(\omega Z_{12b} - \omega_2Z^2_{12b}) = 0 \quad (24)$$

then $\omega_2\times(17) - \omega\times(21)$ which gives,

$$g_1(\omega_2Z_{11b} - \omega Z^2_{11b}) - \omega\omega_2c_1(Z_{11a} - Z^2_{11a}) + g_2(\omega_2Z_{12b} - \omega Z^2_{12b}) - \omega\omega_2c_2(Z_{12a} - Z^2_{12a}) = 0 \quad (25)$$

similarly. (12) – (16) yields,

$$g_2(Z_{22a} - Z^2_{22a}) - c_2(\omega Z_{22b} - \omega_2Z^2_{22b}) + g_1(Z_{12a} - Z^2_{12a}) - c_1(\omega Z_{12b} - \omega_2Z^2_{12b}) = 0 \quad (26)$$

Let,

$$a_1 = Z_{11a} - Z^2_{11a} \quad (27)$$

$$a_2 = Z_{12a} - Z^2_{12a} \quad (28)$$

$$a_3 = Z_{22a} - Z^2_{22a} \quad (29)$$

and

$$b_1 = \omega Z_{11b} - \omega_2Z^2_{11b} \quad (30)$$

$$b_2 = \omega_2Z_{11b} - \omega Z^2_{11b} \quad (31)$$

$$b_3 = \omega Z_{12b} - \omega_2Z^2_{12b} \quad (32)$$

$$b_4 = \omega_2 Z_{12b} - \omega Z_{12b}^2 \quad (33)$$

$$b_5 = \omega Z_{22b} - \omega_2 Z_{22b}^2 \quad (34)$$

$$b_6 = \omega_2 Z_{22b} - \omega Z_{22b}^2 \quad (35)$$

So (24) to (26) can be rewritten as

$$a_1 g_1 - b_1 c_1 + a_2 g_2 - b_3 c_2 = 0 \quad (36)$$

$$b_2 g_1 + a_1 \omega\omega_2 c_1 + b_4 g_2 + a_2 \omega\omega_2 c_2 = 0 \quad (37)$$

$$a_3 g_2 - b_5 c_2 + a_2 g_1 - b_3 c_1 = 0 \quad (38)$$

Solve (36) to (38) for g_1, c_1, and c_2 we get,

$$g_1 = -\frac{a_1 a_2 b_5 \omega\omega_2 + b_1 b_4 b_5 - (b_3)^2 b_4 + a_2 a_3 b_1 \omega\omega_2 - a_1 a_3 b_3 \omega\omega_2 - (a_2)^2 b_3 \omega\omega_2}{\Delta_1} g_2 \quad (39)$$

$$c_1 = -\frac{a_1 b_4 b_5 + a_1 a_3 a_2 \omega\omega_2 - a_2 b_2 b_5 - (a_2)^3 \omega\omega_2 - a_2 b_3 b_4 + a_2 b_2 b_3}{\Delta_1} g_2 \quad (40)$$

$$c_2 = \frac{-a_2 b_1 b_4 + a_3 b_1 b_2 - a_1 (a_2)^2 \omega\omega_2 - a_2 b_2 b_3 + (a_1)^2 a_3 \omega\omega_2 + a_1 b_3 b_4}{\Delta_1} g_2 \quad (41)$$

where

$$\Delta_1 = b_1 b_2 b_5 + (a_1)^2 b_5 \omega\omega_2 - b_2 (b_3)^2 + (a_2)^2 b_1 \omega\omega_2 - 2 a_1 a_2 b_3 \omega\omega_2 \quad (42)$$

If we denote the coefficient of (39)-(41) by n_j, $j=1, 2, 3$, we get,

$$g_1 = n_1 g_2 \quad (43)$$

$$c_1 = n_2 g_2 \quad (44)$$

$$c_2 = n_3 g_2 \quad (45)$$

where

$$n_1 = -\frac{a_1 a_2 b_5 \omega\omega_2 + b_1 b_4 b_5 - (b_3)^2 b_4 + a_2 a_3 b_1 \omega\omega_2 - a_1 a_3 b_3 \omega\omega_2 - (a_2)^2 b_3 \omega\omega_2}{\Delta_1} \quad (46)$$

$$n_2 = -\frac{a_1 b_4 b_5 + a_1 a_2 a_3 \omega\omega_2 - a_2 b_2 b_5 - (a_2)^3 \omega\omega_2 - a_2 b_3 b_4 + a_2 b_2 b_3}{\Delta_1} \quad (47)$$

$$n_3 = \frac{-a_2 b_1 b_4 + a_3 b_1 b_2 - a_1 (a_2)^2 \omega\omega_2 - a_2 b_2 b_3 + (a_1)^2 a_3 \omega\omega_2 + a_1 b_3 b_4}{\Delta_1} \quad (48)$$

Substitute g_1, c_1, c_2 to (17)

$$n_1 g_2 Z_{11b} + Z_{11a} \omega n_2 g_2 - r_1 \omega n_2 g_2 + \omega n_3 g_2 Z_{12a} + g_2 Z_{12b} = 0 \quad (49)$$

if $g_2 \neq 0$, we can solve (49) for r_1 as follows

$$r_1 = \frac{n_1 Z_{11b} + Z_{11a} \omega n_2 + \omega n_3 Z_{12a} + Z_{12b}}{\omega n_2} \quad (50)$$

Similarly we can get r_2 from (19)

$$r_2 = \frac{n_1 Z_{11b} + Z_{22a} \omega n_3 + \omega n_2 Z_{12a} + Z_{22b}}{\omega n_2} \quad (51)$$

Substitute g_1, c_1, c_2 and r_1 to (16), we can determine g2.

$$g_2 = -\frac{\omega n_2}{(n_1)^2 Z_{11b} + n_1 n_3 Z_{12a} \omega + n_1 Z_{12b} - n_2 Z_{12a} \omega + n_2 n_3 Z_{12b} (\omega)^2 + (n_2)^2 Z_{11b} (\omega)^3} \quad (52)$$

After g_2 is determined, g_1, c_1, c_2 can be calculated from (43) to (45). So far, the only parameter left undetermined is Z, which can be calculated at frequency ω from (10) as

$$Z = \frac{\frac{1}{Z_{12}} - g_1 - g_2 - j\omega c_1 - j\omega c_2}{(g_1 + j\omega c_1)(g_2 + j\omega c_2)} \tag{53}$$

Appendix 3

Further discussions on Identification Results

In Appendix 2 we got a set of symbolic solutions to all the parameters in the enhanced model. The results are repeated here,

$$r_1 = \frac{n_1 Z_{11b} + Z_{11a}\omega n_2 + \omega n_3 Z_{12a} + Z_{12b}}{\omega n_2} \quad (1)$$

$$r_2 = \frac{n_1 Z_{11b} + Z_{22a}\omega n_3 + \omega n_2 Z_{12a} + Z_{22b}}{\omega n_2} \quad (2)$$

$$g_2 = -\frac{\omega n_2}{(n_1)^2 Z_{11b} + n_1 n_3 Z_{12a}\omega + n_1 Z_{12b} - n_2 Z_{12a}\omega + n_2 n_3 Z_{12b}(\omega)^2 + (n_2)^2 Z_{11b}(\omega)^3} \quad (3)$$

$$g_1 = n_1 g_2 \quad (4)$$

$$c_1 = n_2 g_2 \quad (5)$$

$$c_2 = n_3 g_2$$

$$Z = \frac{\frac{1}{Z_{12}} - g_1 - g_2 - j\omega c_1 - j\omega c_2}{(g_1 + j\omega c_1)(g_2 + j\omega c_2)} \quad (6)$$

where ω is test frequency, Z_{iju} and Z_{ijb}, $i=1,2$, $j=1,2$ are the real and imaginary parts of the Z-parameters respectively, and n_k, $k=1,2,3$ can be calculated as follows,

$$n_1 = -\frac{a_1 a_2 b_5 \omega\omega_2 + b_1 b_4 b_5 - (b_3)^2 b_4 + a_2 a_3 b_1 \omega\omega_2 - a_1 a_3 b_3 \omega\omega_2 - (a_2)^2 b_3 \omega\omega_2}{\Delta_1} \quad (7)$$

$$n_2 = -\frac{a_1 b_4 b_5 + a_1 a_2 a_3 \omega\omega_2 - a_2 b_2 b_5 - (a_2)^3 \omega\omega_2 - a_2 b_3 b_4 + a_2 b_2 b_3}{\Delta_1} \quad (8)$$

$$n_3 = \frac{-a_2 b_1 b_4 + a_3 b_1 b_2 - a_1 (a_2)^2 \omega\omega_2 - a_2 b_2 b_3 + (a_1)^2 a_3 \omega\omega_2 + a_1 b_3 b_4}{\Delta_1} \quad (9)$$

where

$$\Delta_1 = b_1 b_2 b_5 + (a_1)^2 b_5 \omega\omega_2 - b_2 (b_3)^2 + (a_2)^2 b_1 \omega\omega_2 - 2a_1 a_2 b_3 \omega\omega_2 \quad (10)$$

and a_k, k=1,2,3, b_j, j=1...6 can be calculated directly from the knowns(See [1] for their definations)

One problem with this set of formula is that Δ_1 can be zero for some particular measurement values. In this case, an alternative has to be found to calculate the parameters. Taking into

consideration the condition that Δ_1 is zero, another set of formula can be obtained as shown in the follows.

$$r_1 = -\frac{-Z_{11a}\omega a_2 b_5 + Z_{11a}\omega a_3 b_3 - Z_{12b}b_1 b_5 + Z_{12b}(b_3)^2 - Z_{12a}\omega a_3 b_1 + Z_{12a}\omega a_2 b_3}{\omega(a_2 b_5 - a_3 b_3)} \quad (11)$$

$$r_2 = \frac{Z_{22a}\omega a_1 b_3 - Z_{22a}\omega a_2 b_1 - Z_{12b}b_1 b_5 + Z_{12b}(b_3)^2 - Z_{12a}\omega a_1 b_5 + Z_{12a}\omega a_2 b_3}{\omega(a_1 b_3 - a_2 b_1)} \quad (11)$$

$$g_2 = \frac{s_2 - m_2}{m_1 s_2 - m_2 s_1} \quad (13)$$

$$c_2 = \frac{m_1 - s_1}{m_1 s_2 - m_2 s_1} \quad (14)$$

$$c_1 = q_1 c_2 + q_2 g_2 \quad (15)$$

$$c_1 = p_1 c_2 + p_2 g_2 \quad (16)$$

where

$$m_1 = Z_{11a} p_2 - \omega Z_{11b} q_2 - r_1 p_2 + Z_{12a} \quad (17)$$

$$m_2 = Z_{11a} p_1 - \omega Z_{11b} q_1 - r_1 p_1 + \omega Z_{12b} \quad (18)$$

$$s_1 = Z_{22a} - r_2 + Z_{12a} p_2 - \omega Z_{12b} q_2 \quad (19)$$

$$s_2 = -\omega Z_{22b} + Z_{12a} p_1 - \omega Z_{12b} q_1 \quad (20)$$

and

$$p_1 = \frac{(b_3)^2 - b_1 b_5}{a_1 b_3 - a_2 b_1} \quad (21)$$

$$p_2 = \frac{a_2 b_1 - a_2 b_3}{a_1 b_3 - a_2 b_1} \quad (22)$$

$$q_1 = \frac{a_2 b_3 - a_1 b_5}{a_1 b_3 - a_2 b_1} \quad (23)$$

$$q_2 = \frac{a_1 a_3 - (a_2)^2}{a_1 b_3 - a_2 b_1} \quad (24)$$

Appendix 4

Line termination

The line is usually terminated by a resistance R in series with a capacitor C, which is paralleled by the loop resistance and capacitors. To determine the termination is to identify all these parameters. In Appendix 1 and 2 we have got the equivalent impedance Z or admittance of the termination Y at two frequencies when we identify the model parameters. We now considering using admittance representation. From Figure 9 we have

$$Y = g + j\omega c_1 + \frac{j\omega c_2}{1 + j\omega Rc_2} \tag{1}$$

Let

$$Y = a + jb \tag{2}$$

where a and b are the real and imaginary part of Y respectively. So

$$a = g + \frac{\omega^2 Rc_2^2}{1 + \omega^2 R^2 c_2^2} \tag{3}$$

$$b = \omega c_1 + \frac{\omega c_2}{1 + \omega^2 R^2 c_2^2} \tag{4}$$

Let

$$Rc_2 = x \tag{5}$$

and measure the Y at two frequencies ω_1 and ω_1. we have

$$a_1 - a_2 = \frac{\omega_1^2 xc_2}{1 + \omega_1^2 x^2} - \frac{\omega_{21}^2 xc_2}{1 + \omega_2^2 x^2} \tag{6}$$

and

$$\frac{b_1}{\omega_1} - \frac{b_2}{\omega_2} = \frac{c_2}{1 + \omega_1^2 x^2} - \frac{c_2}{1 + \omega_2^2 x^2} \tag{7}$$

(6)/(7) we have

$$\frac{a_1-a_2}{\frac{b_1}{\omega_1}-\frac{b_2}{\omega_2}}=\frac{\frac{\omega_1^2 x}{1+\omega_1^2 x^2}-\frac{\omega_2^2 x}{1+\omega_2^2 x^2}}{\frac{1}{1+\omega_1^2 x^2}-\frac{1}{1+\omega_2^2 x^2}}$$

$$=x\frac{\omega_1^2\left(1+\omega_2^2 x^2\right)-\omega_2^2\left(1+\omega_1^2 x^2\right)}{\left(1+\omega_2^2 x^2\right)-\left(1+\omega_1^2 x^2\right)} \qquad (8)$$

$$=x\frac{\omega_1^2-\omega_2^2}{\omega_2^2 x^2-\omega_1^2 x^2}$$

$$=-\frac{1}{x}$$

i.e.

$$x=-\frac{\frac{b_1}{\omega_1}-\frac{b_2}{\omega_2}}{a_1-a_2}=\frac{1}{\omega_1\omega_2}\frac{\omega_2 b_1-\omega_1 b_2}{a_2-a_1} \qquad (9)$$

After we get x, c_2 can be calculated from (6), which gives

$$c_2=\frac{(a_1-a_2)\left(1+\omega_1^2 x^2\right)\left(1+\omega_2^2 x^2\right)}{x\left(\omega_1^2-\omega_2^2\right)} \qquad (10)$$

and R from (5)

$$R=\frac{x}{c_2} \qquad (11)$$

So g and c1 can be determined from (3) and (4) respectively

$$g=a_1-\frac{\omega_1^2 x c_2^2}{1+\omega_1^2 x^2} \qquad (12)$$

and

$$c_1=\frac{b_1}{\omega_1}-\frac{c_2}{1+\omega_1^2 x^2} \qquad (13)$$

CLAIMS

1. A method of testing a telecommunications system, the method comprising;

1) applying a first AC test signal having a first signal frequency to the system and measuring the response of the system to the first test signal;

2) applying a second AC test signal having a second signal frequency different to the first signal frequency to the system and measuring the response of the system to the second test signal; and

3) calculating one or more parameters of the system from the responses measured in steps 1) and 2).

2. A method according to claim 1 wherein the first and second test signals are applied at different times.

3. A method according to claim one or two wherein one or both of the test signals has a substantially sinusoidal waveform.

4. A method according to any of the preceding claims wherein less than five cycles of each signal is applied to the system.

5. A method according to any of the preceding claims wherein the test signals are each applied to the system through a known impedance.

6. A method according to any of the preceding claims further comprising applying;

4) applying one or more additional test signals to the system and measuring the response of the system to the or each test signal; and

wherein step 3) comprises calculating one or more parameters of the system from the responses measured in steps 1),2) and 4).

7. A method according to any of the preceding claims wherein the system comprises first and second transmission lines, and wherein each step of applying a test signal and measuring the response of the system comprises

a) applying the test signal to the first line and monitoring the response of the first line and the second line to the test signal; and

b) applying the test signal to the second line and monitoring the response of the second line and the first line to the second test signal.

8. A method of testing a telecommunications system comprising first and second transmission lines, the method comprising

1) applying a first test signal to the first line and measuring the response of the first line and the second line to the first test signal;

2) applying a second test signal to the second line and measuring the response of the second line and the first line to the second test signal; and

3) calculating one or more parameters of the telecommunications system from the responses measured in steps 1) and 2).

9. A method according to any claim 8 wherein the first and second signals each comprise AC signals.

10. A method according to claim 9 wherein the signal frequencies of the first and second test signals are substantially identical.

11. A method according to claim 10 wherein the first and second test signals have a known phase relationship.

12. Apparatus for testing a telecommunications system, the apparatus comprising;

1) means for applying a first AC test signal having a first signal frequency to the system;

2) means for measuring the response of the system to the first test signal;

3) means for applying a second AC test signal having a second signal frequency different to the first signal frequency to the system;

4) means for measuring the response of the system to the second test signal; and

5) means for calculating one or more parameters of the system from the responses measured in steps 1) and 2).

13. Apparatus for testing a telecommunications system comprising first and second transmission lines, the apparatus comprising

1) means for applying a first test signal to the first line

2) means for measuring the response of the first line and the second line to the first test signal;

3) means for applying a second test signal to the second line

4) means for measuring the response of the second line and the first line to the second test signal; and

5) means for calculating one or more parameters of the telecommunications system from the responses measured in steps 1) and 2).

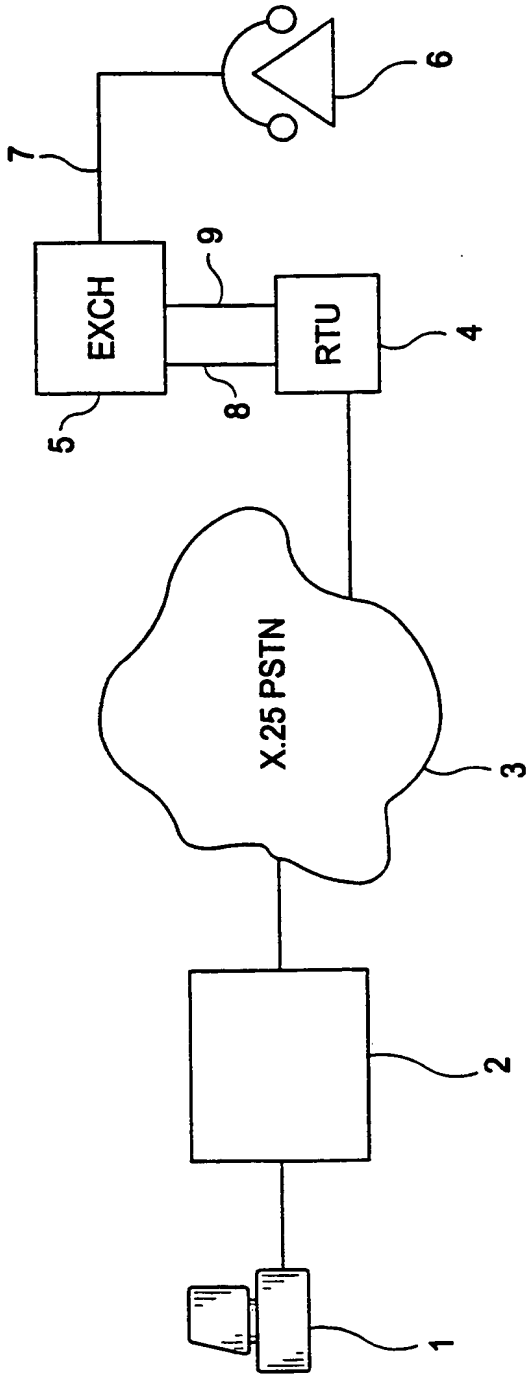


FIG-1

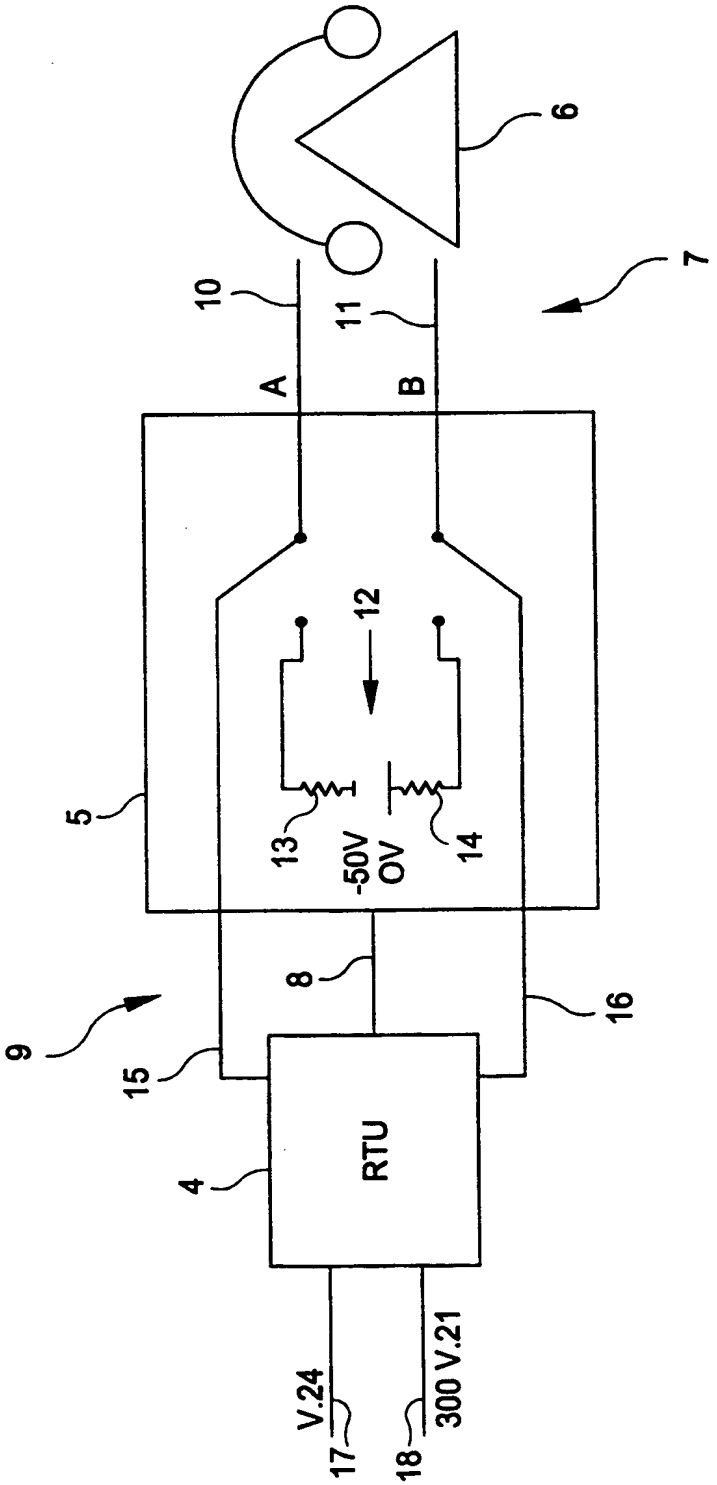


FIG-2

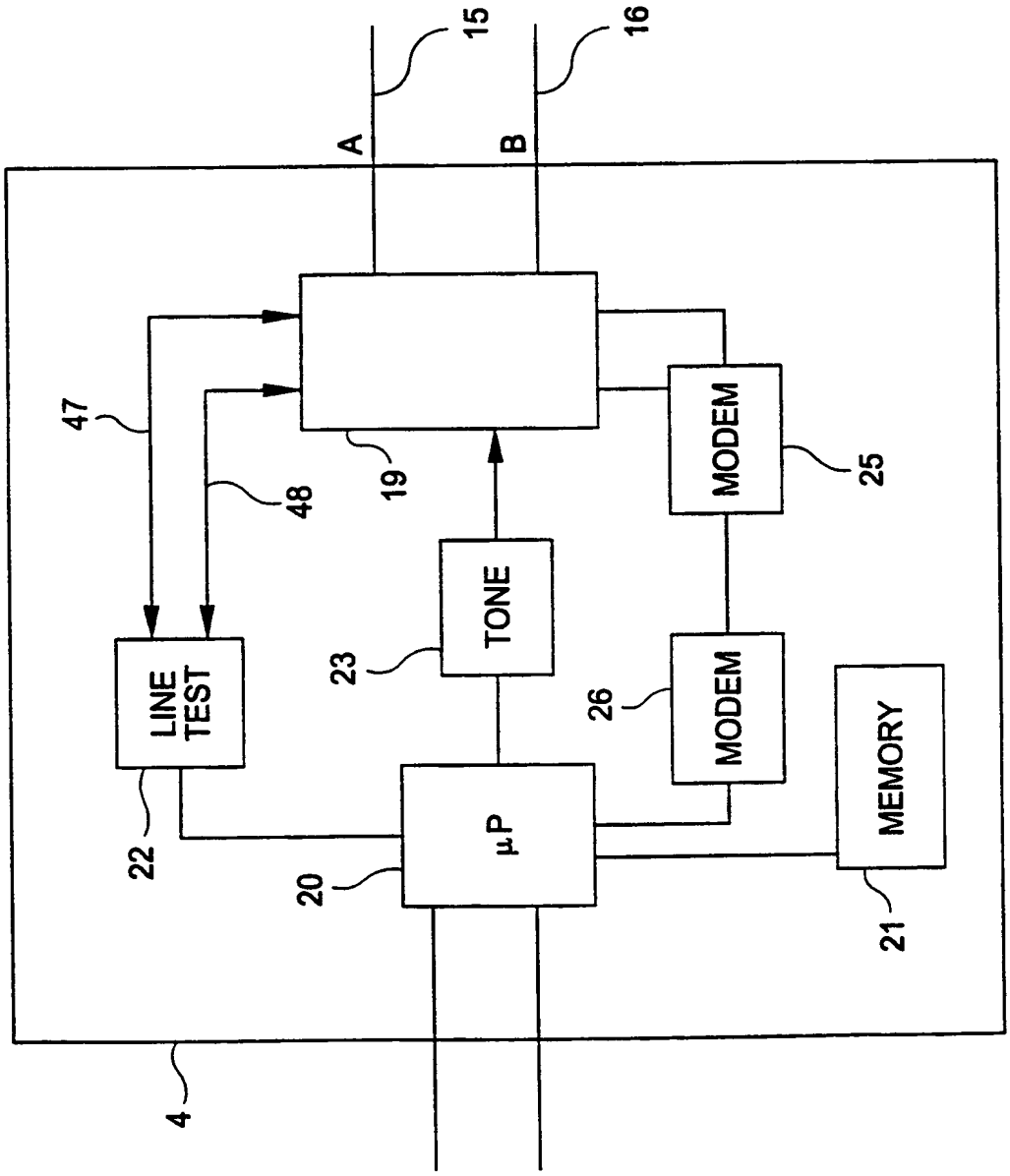
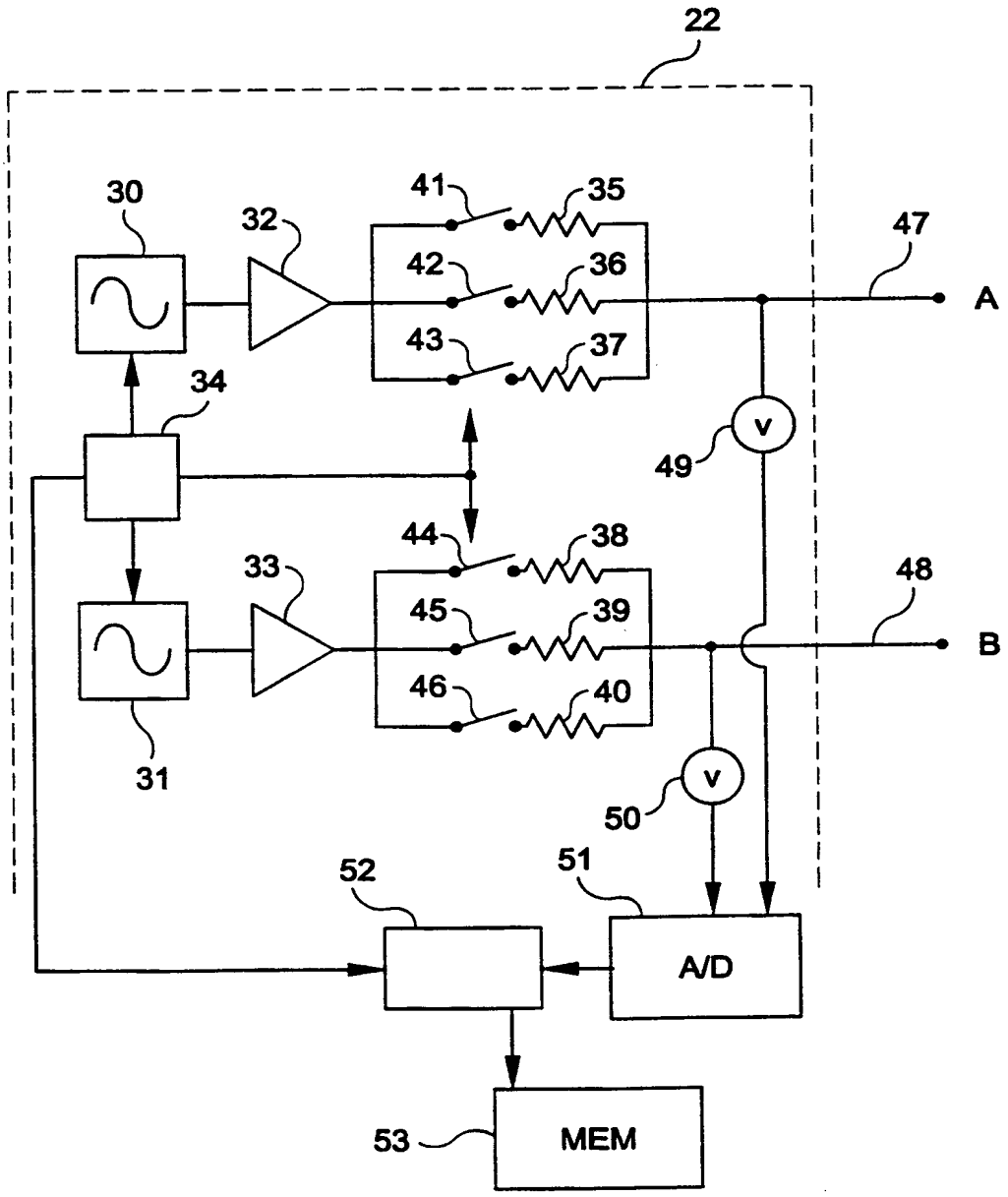

15
16
A
B
47
48
19
MODEM
25
TONE
23
LINE TEST
22
26
MODEM
MEMORY
μP
20
21
4

FIG-3

FIG-4


22
30
32
41
35
42
36
43
37
47
A
34
49
V
44
38
33
45
39
48
B
46
40
31
V
50
52
51
A/D
53
MEM

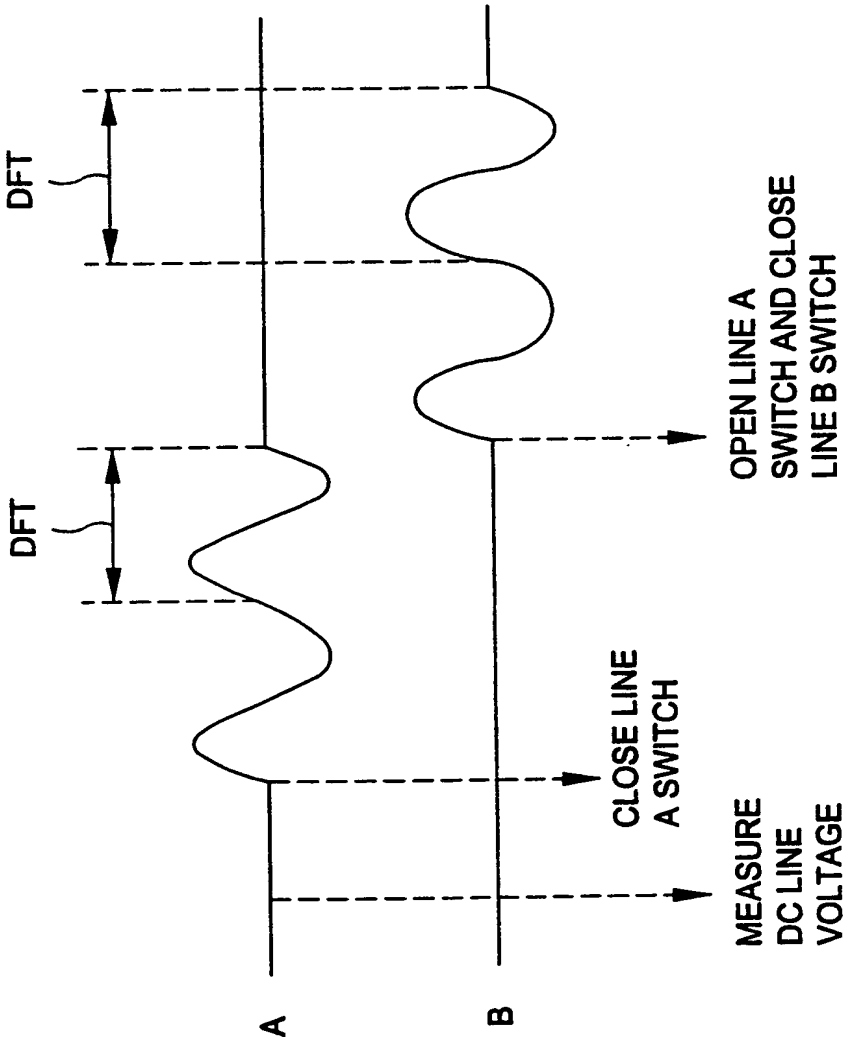

DFT
DFT
OPEN LINE A SWITCH AND CLOSE LINE B SWITCH
CLOSE LINE A SWITCH
MEASURE DC LINE VOLTAGE
A
B

FIG-5

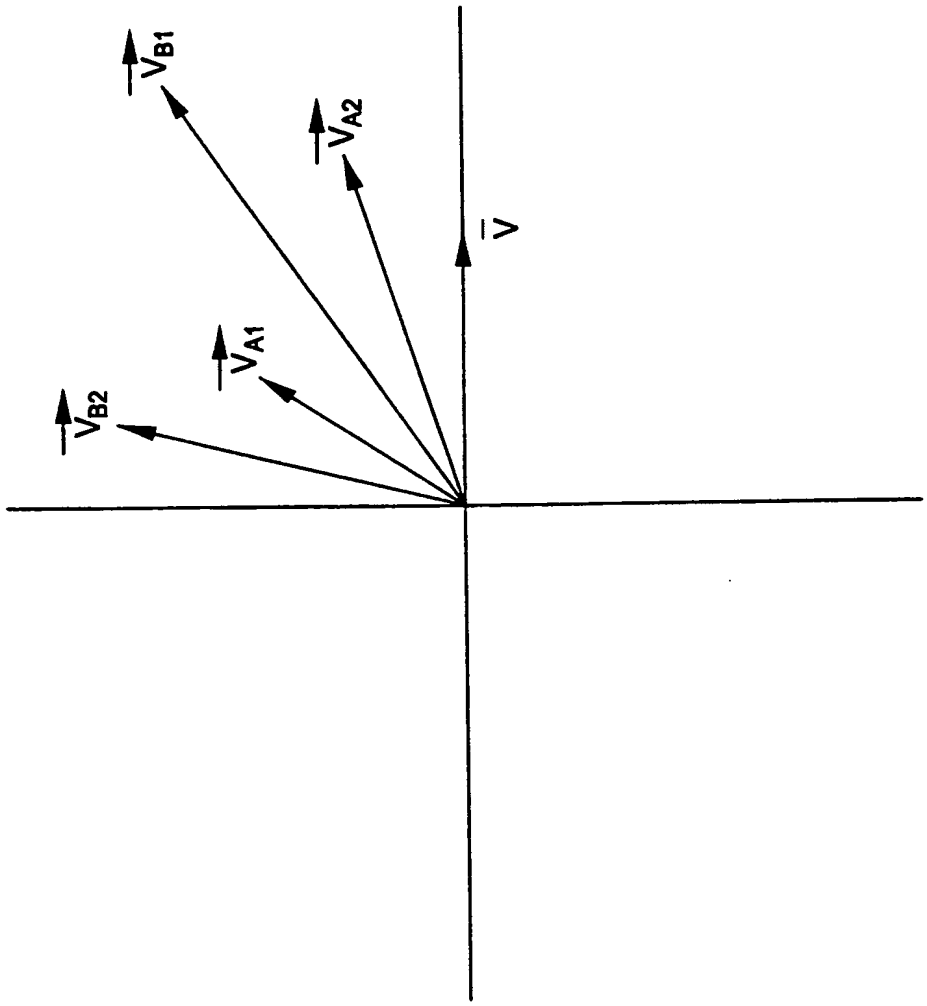


FIG-6

FIG-7

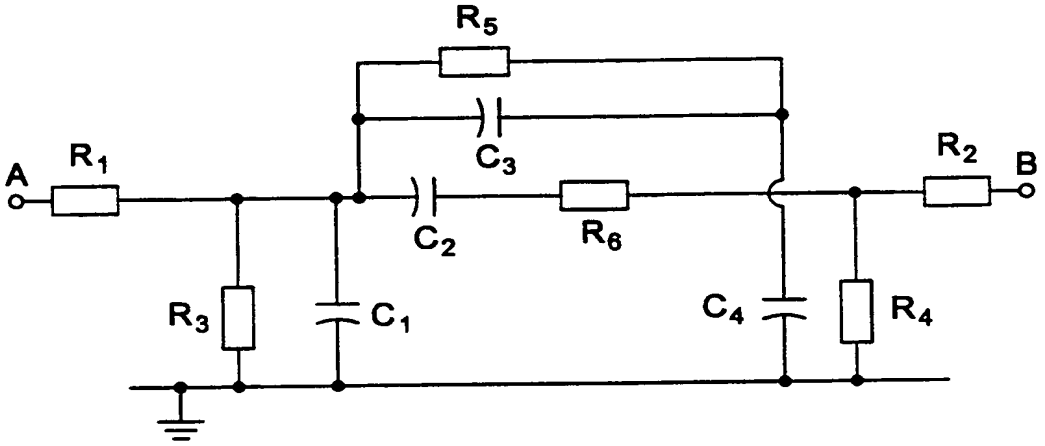


FIG-8

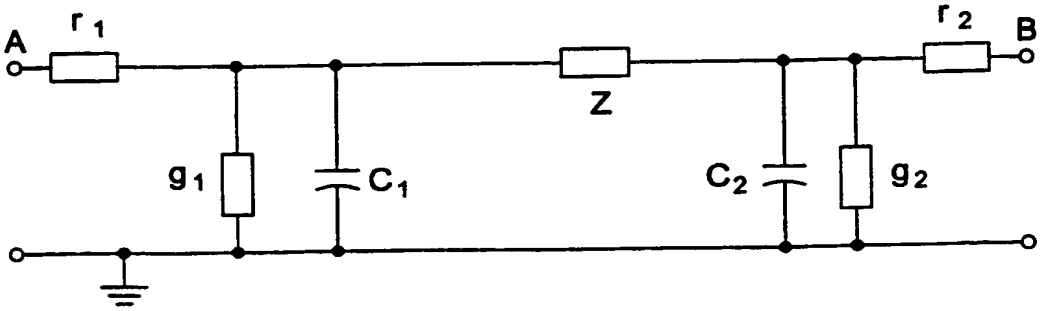


FIG-9

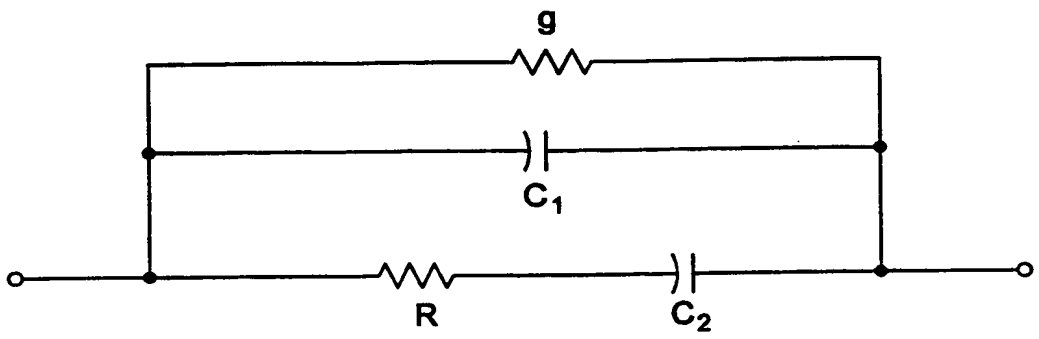


FIG-10